THIS PROPOSED PLAN

CAN CHANGE

THE SALTON SEA

INTO A

FRESHWATER LAKE

AND DO IT

PROFITABLY!

Salton Sea Restoration

Lake Cahuilla

Proposal

Solar Salt Gradient Pond/Plants
(SPPs)

By
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Overview

We propose a power and water system, a "Solar Power & Water Farm", using a salt gradient solar pond and a new prime mover (engine) designed to extract power directly from the pond's hot brine. Salt gradient solar ponds were not invented; they were discovered in nature and first observed in Transylvania in the early 1900s. Solar ponds work in winter, even when covered with a sheet of ice and surrounded by drifts of snow. The new prime mover design is a derivative from a prior machine, which operated for thousands of hours, until testing was terminated by the funding agencies. The pond and engine are existing technology, which combined as in this proposal offer advanced technology.

This proposal involves solar-based technology that produces both fresh water and power from agricultural wastewater, brackish/saline water, or ocean water. The problems with the Salton Sea are well studied, and this technology is a solution to its restoration, to the point of actual conversion into a fresh water lake of desired elevation. A brief description of the technology is included in this proposal. The accompanying proposal CD contains a full description, along with references.

This technology can also be used with the waste brine stream produced by reverse osmosis (RO) desalination. It is important to point out that the fresh water output of RO membranes is temperature dependant. Raising the feed temperature from 70ºF to 110ºF doubles the output. This can be done using a little of the heat in the pond. Increased membrane output, plus cheap in-house power driving the RO process, significantly reduces costs. The net result is a combined plant that produces low cost fresh water and power. A solar-based desalination plant also being a power plant is a new concept offering tremendous benefits.

Throughout the State of California, the potential exists for thousands of megawatts and millions of ac-ft/yr of fresh water.

This proposal is not a short-term quick fix for the Sea; it is a permanent long-term sustainable solution. The solar power produced makes the proposal extremely attractive.

On a global scale, this technology can fill a vast need.

Contents

The Problem

The Salton Sea is becoming a 300 square mile blighted dead sea valued only as a shrunken terminal for agricultural runoff, with increasingly serious environmental and economic consequences. Reversing this process by removing salts and stabilizing the elevation involves present designs, considered by the Salton Sea Authority, that are both costly to build and to maintain. Much work has been done by many people and organizations to find an acceptable solution the public would be willing to pay for. Success would be of great public benefit in many ways.

For relatively little money, the plan proposed here can be tested.

Preface

Here is an expanded and enhanced version of the Imperial Valley Proposal previously submitted to the Salton Sea Authority, now called the Lake Cahuilla Proposal. The Imperial Valley Proposal and the enhanced version, the Lake Cahuilla Proposal, follow the Salton Sea Authority Guidelines for "Submitting Unsolicited Proposals to Restore the Salton Sea".

The Lake Cahuilla Plan involves installing first one and then 200 (fewer if larger) Solar Salt Gradient Pond/Plants (SPPs) on the Sea. The plan also involves installations in the Colorado River Basin and Delta, along the Gulf, and on the wastewaters flowing into the Sea.

The enhanced plan entails pumping poor quality water from groundwater sources for feeding the Sea, and injecting a corresponding volume of Sea water at suitable depth near the Sea. The result is an unambiguous benefit to the Sea, which starts early. Later, the previously injected Sea water can be pumped back out and used to supply SPPs. Additional water is available by following the U S Bureau of Reclamation 1999 Salton Sea Alternatives "Other Possible Long Term Actions" to import Central Arizona Salinity Interceptor Water. Except in the Lake Cahuilla Plan, the routing would be of SPP fresh water via the Colorado River and the All-American to the Coachella Canal.

Heavy brines, including contaminants such as selenium, from the proposed SPPs will be disposed of by the best-determined means, such as deep injection.

This Lake Cahuilla Plan can be compared with the Authority's Preferred Plan. The Salton Sea Authority Preferred Plan states:

"Cost and Financing
The construction cost of the program for a design elevation of -235 feet msl is estimated at between $650 and $730 million based on a conceptual-level cost analysis. This estimate includes the mid-Sea retention structure/causeway, appurtenances, dredging to communities, greenbelt channels to the north lake, a fresh water recreational lake, Torres Martinez wetlands/habitat, upstream wetlands, and an initial phase of shallow water habitat construction. Total annual operating expenses are estimated at about $10 million, including costs for maintenance of the mid-Sea retention structure, appurtenances and channels, and for future expansion and maintenance of shallow water habitat areas."

Plan Comparison

Item	Preferred Plan	Lake Cahuilla Plan
Design Elevation, Feet msl	**-235**	**-228**
Program Construction Cost est., $Mil.	**650 to 730**	**139**
Mid-Sea Retention Structure/Causeway	**Yes**	**None**
Appurtenances	**Yes**	**None**
Dredging to Communities	**Yes**	**None**
Greenbelt Channels to the North Lake	**Yes**	**None**
Fresh Water Recreational Lake	**Yes**	**Whole Sea**
Torres Martinez Wetlands/Habitat	**Yes**	**Natural**
Upstream Wetlands	**Yes**	**Natural**
Appurtenances and Channels	**Yes**	**None**
Initial Phase Shallow Water Habitat	**Yes**	**Natural**
Future, Shallow Water Habitat Areas	**Yes**	**Natural**
Annual Operation Expenses est., $Mil.	**10**	**Income**

In the Evaluation of Restoration Options considered by the Authority, Table ES-1, Ref. 9, the Option with the highest rating became the Preferred Plan. The Lake Cahuilla Plan gets a still higher rating. The rating is based on ranking 12 objectives where the highest ranking is given a number "1" and the lowest a "4". Only in the objective "High Safety Rating/Low Risk of Failure" does the Lake Cahuilla Plan fail to get the top ranking of 1, getting a 2 instead. The basis for a 2 ranking in this objective is the following:

1. The Lake Cahuilla Plan follows the adage "First, Do No Harm".

2. Replacement of Sea water with ground water is an unambiguous benefit and starts early. Additionally it could benefit farmland, depending on what groundwater is removed.

3. The SPP team is composed of the key members behind a proposal for construction and testing of a novel geothermal engine, which was awarded 11.2% of the total U.S. Government's geothermal budget for 1975 during the energy crisis. The SPP engine is an improved direct descendant of the earlier machine. This earlier machine met the proposal objectives. Subsequent testing was requested by CFE - Mexico, ENEL - Italy, and Ministry of Works - New Zealand. The subsequent testing was carried out sequentially on their sites with additional funds. Note: Seismic concerns must be considered in risk assessment. The earlier machine was operating in Cierro Prieto, Mexico, during an earthquake of magnitude 6.7, epicenter 1/4 mile away. The machine shifted 3/4" on its base but was unharmed. The extent to which a salt gradient pond might be upset by a seismic event is unknown, but recovery would be a minor problem.

Should testing of the first SPP indicate lower than predicted machine efficiency, compensation is available by increasing the pond size to allow a higher flow rate of hot brine through the machine, with the interesting consequence that the fresh water yield of the SPP is increased. The testing will allow assessment of the pond under high wind conditions and also the practicability of larger plants and ponds.

It should also be noted that by increasing the number of SPPs above the plan, salinity reduction of the sea is accelerated. Moreover, SPPs are candidates for funding by utilities wanting renewable solar power to meet their Renewable Portfolio Standard goals. Only the water is needed to freshen the Sea.

For planning purposes, the elevation and ultimate salinity of the whole Sea should be selected collectively soon by old vested interests including marinas, seaside campgrounds, the Torres Martinez tribe, naturalists, and real estate owners.

Benefits to the Imperial Valley are left to the imagination of the reader.

Summary

Submitted herein is a proposal to use Solar Salt Gradient Pond/Plants (SPPs) for the restoration of the Salton Sea and its conversion into a fresh water lake, to once again become Lake Cahuilla. The plan involves locating 200 (or fewer larger) SPPs adjacent to the Sea to join the process of reducing the Sea's salinity. These SPPs will be followed by additional SPPs located throughout the Colorado River Basin and Delta or along the Gulf to stabilize the Sea's elevation. Water to stabilize the Sea's elevation involves water swaps which can be delivered via the Colorado River and Coachella Canal. The Salton Sea Restoration, Alternatives Packet (November 2-4 1999, page 33) shows the possible importation of Central Arizona Salinity Interceptor Water. This source alone, with SPPs located in Arizona, appears adequate to stabilize the Sea's elevation.

In order to bring the Sea's salinity down early, during the first years of SPP construction, the proposal includes injecting Sea water into a nearby aquifer and supplying water to the Sea as needed from wells located along IID's agricultural waste canals for drainage into the Sea. At a later date, the injection wells can be reversed and fitted with pumps to recover the injected water and supply additional SPPs.

The estimated cost for the Sea water injection program during the construction and testing of the first SPP adds another \$19 million to the \$2 million for only constructing and testing the SPP. If the SPP is deemed not suitable for restoring the Sea, the Sea water injection can be continued or stopped. Either way, the Sea benefits with diminished salinity. At this point the Lake Cahuilla plan would be terminated.

Ultimate salt disposal will be by the best-determined means, such as deep injection.

Total SPP plant weight is estimated at 160,000 lbs. Estimated cost for the first unit is \$1,994,000, or ~\$2 million. Installed using Salton Sea water, the estimated annual income from it is \$703,000, as shown in Figure 1, p. 13, and on pages 25 and 26.

SPPs concentrate salts, similar to concentrating ponds, but they do it on about half the acreage. They produce fresh water and sustainable solar power.

Farther afield, SPPs can utilize low quality ground water. Millions of ac-ft of saline groundwater exist in aquifers around and under the Salton Sea. SPPs can be used to convert the saline water in these aquifers to fresh water. The elevation of the Sea can also be stabilized by selectively pumping water into or out of the aquifers. Excess water can be exported.

This technology is solar-based desalination and power production. A major new piece of equipment is the prime mover (engine) that extracts power directly from the heat energy found in warm (~160ºF) waters and brine. The technology is sustainable, renewable, and low cost. The plants will be profitable and could be privately financed.

The Plan

The plan is shown graphically in the following Timeline graph, page 11.

The execution of this plan involves first the construction and installation of one SPP, which is a 60-acre solar salt gradient pond/plant, along with the installation of supply and disposal wells.

The SPP design along with installation costs, operating costs, and income, are presented in detail following the Timeline graph.

The supply wells are needed to keep the Sea elevation from falling while Sea water with its salts are removed by local well injection. The supply wells can be located throughout the Imperial Valley where there is brackish water, power available, and a drainage method into the Sea. Installing supply wells throughout farming areas where the water table is high (and undesirable) would serve a double purpose. Locating adjacent to existing tail-water ditches and sump pumps appears logical and convenient.

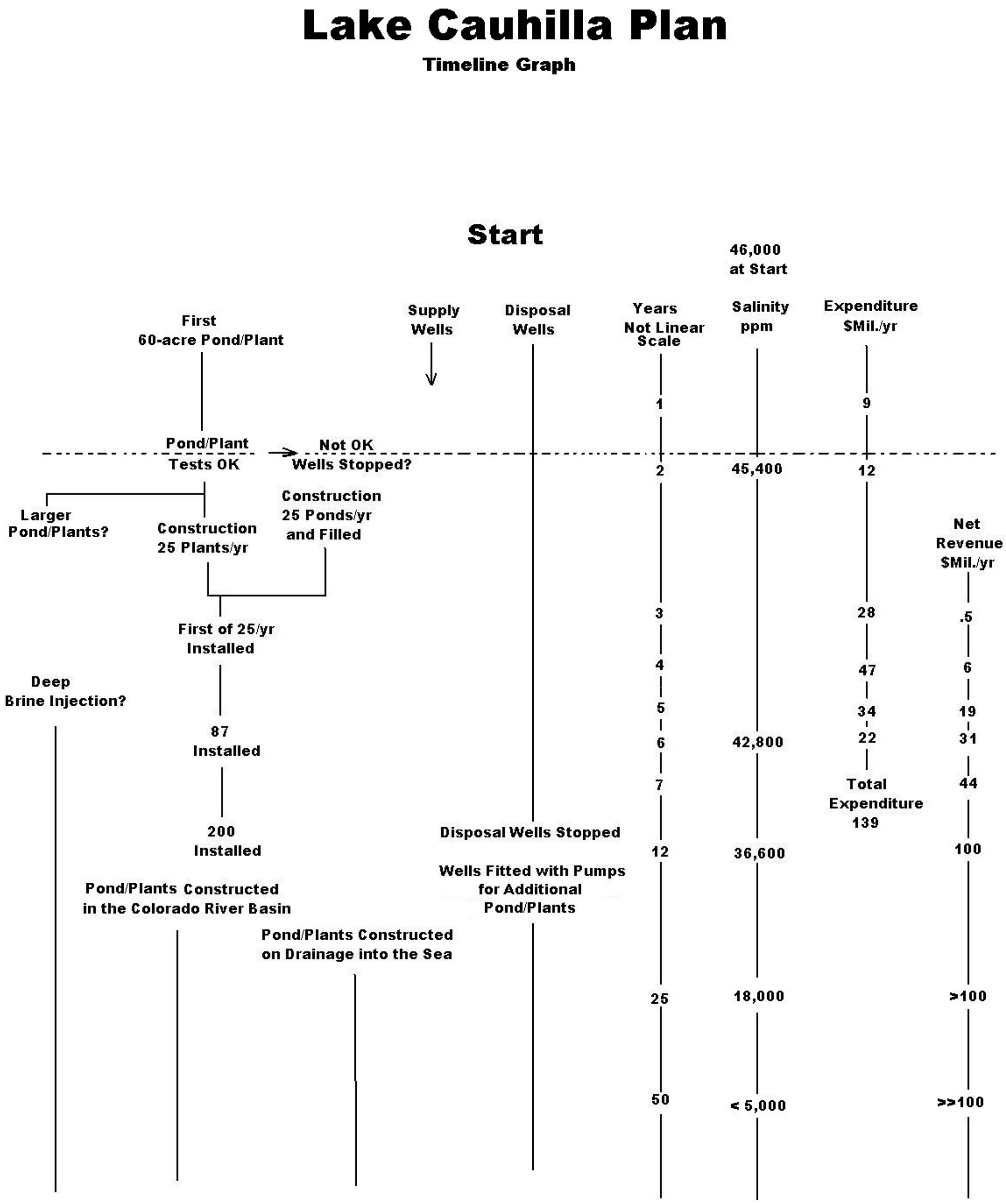
Saline aquifers exist around and under the Sea. The plan is to inject 150,000 ac-ft/yr into one or more of these aquifers early in the project to begin the salinity reduction. Possibly local shallower, less saline aquifers can be simultaneously pumped into the Sea to maintain a stable water table.

A convenient location for the first SPP is next to one of the terminal drainages flowing into the Sea. Construction time for the first plant is 18 months. The time period to evaluate the performance should be a few months. However, one of the needs in evaluating the performance is the pond's ability to survive high winds, which is impossible to schedule. 6 months is estimated.

Assuming the first SPP performs as predicted, construction can begin on multiple installations. The plan is for 25 per year, and the salinity reduction is shown in the Timeline. This can be more or less as determined by the Cognizant Agency.

After the planned 200 SPPs (fewer if larger) are installed, construction can continue at the same pace on installations throughout the Colorado River Basin, Delta, or Gulf. These are the SPPs that will be the long-term suppliers of fresh water, via the Colorado River and Coachella Canal, to maintain a stable Sea elevation. The number of these plants is unknown. However, assuming these plants are economically viable, it may be decided to continue construction indefinitely beyond elevation control needs.

The final step in converting the Sea into a fresh water lake involves approximately 270 (fewer if larger) installations with RO on the waste drainage flowing into the Sea. These can be phased in as determined at that time. Placement of the SPPs on the Sea or intercepting the drainage will be determined by the performance and the salinities. With the Sea as a fresh water lake and all the waste drainage intercepted, only a few installations (with RO) will be needed on the Sea, to be once again called Lake Cahuilla.



The Design

The Design Using Salton Sea Water

The following primary references are basic to the design of the proposal:

1) "Comparison of Solar Pond Concepts for Electrical Power Generation" Battelle, Pacific Northwest Laboratories, October 1975

2) "A State-of-the-Art Study of Nonconvective Solar Ponds for Power Generation" MIT, January 1985

3) "Helical Screw Expander Evaluation Report" Richard McKay Final Report to DOE Through an Agreement with NASA, by JPL. March 1, 1982 DOE/ET-28329-1, Distribution Category UC-66D NTIS # DE82013337

4) "Test and Demonstration of a 1-MW Wellhead Generator: Helical Screw Expander Power Plant, Model 76-1" (Richard McKay) DOE Final Report to the International Energy Agency. July 4, 1985 DOE/CE-0129 NTIS # DE85016049

5) "Desalination and Power Production from Low Enthalpy Hot Waters using Large Hollow Rotor Helical Screw Prime Movers", Sprankle, R., March 2004

6) "Final Report" Salton Sea Solar Pilot Pond Project, Agrarian Research and Management Company, June 2003

7) "Parson's Executive Summary to the Salton Sea Authority, 2001

8) "Treatment and Reuse of Agricultural Drainage Waters", Matsumoto, Mark R, Task 2.4 A1 submitted to: California Energy Commission, January 2002

9) "Final Preferred Project Report", Salton Sea Restoration, July 2004

10) "Imperial Valley Proposal", Roger Sprankle, January 2005

Inputs/Outputs

Figures 1, 2, and 3 show the pond inputs/outputs using Salton Sea water, the brine flow loop within the pond, and the layout of the plant. Figure 4 shows the inputs/outputs using agricultural wastewater with RO. The flow rates and power output are based upon the average solar insolation for the Imperial Valley. Seasonal swings are discussed later.

Water and Power

"Farm"

Cost = $1,994,000

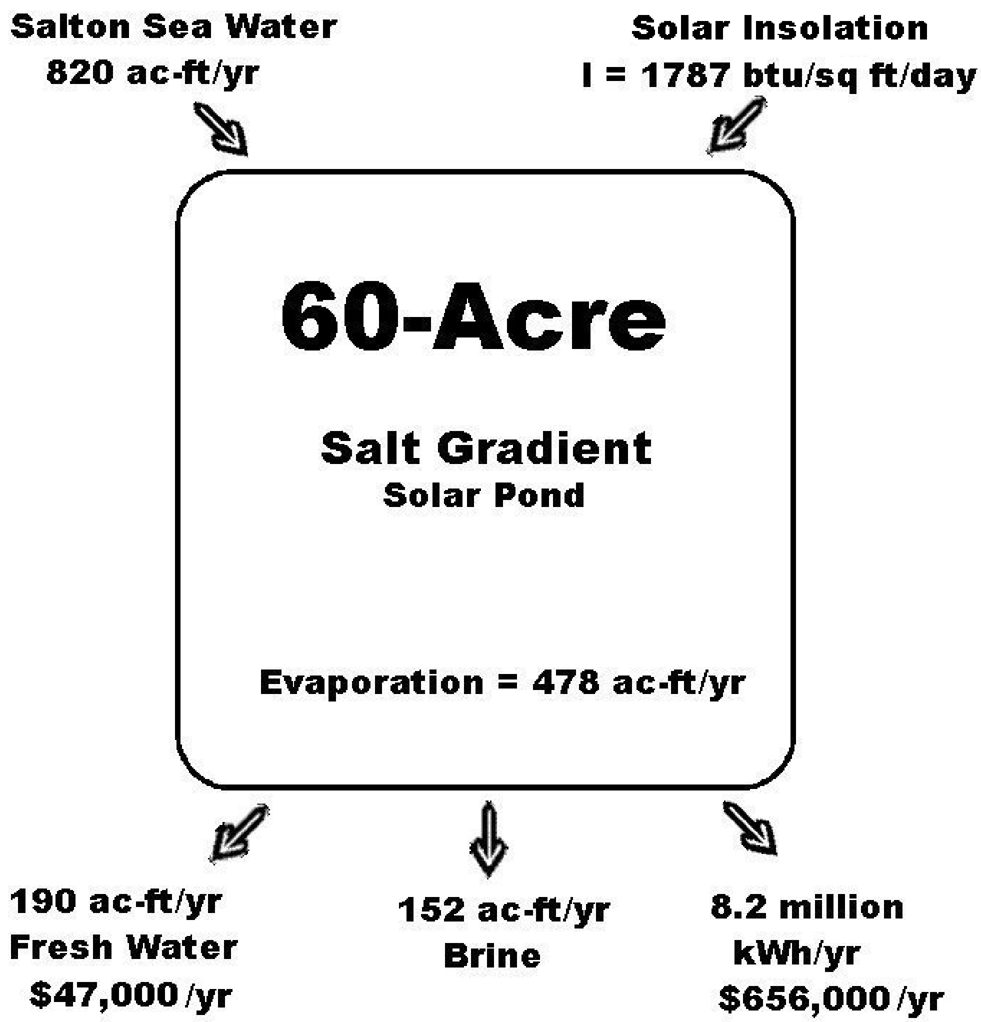


Figure 1

Brine Flow Loop

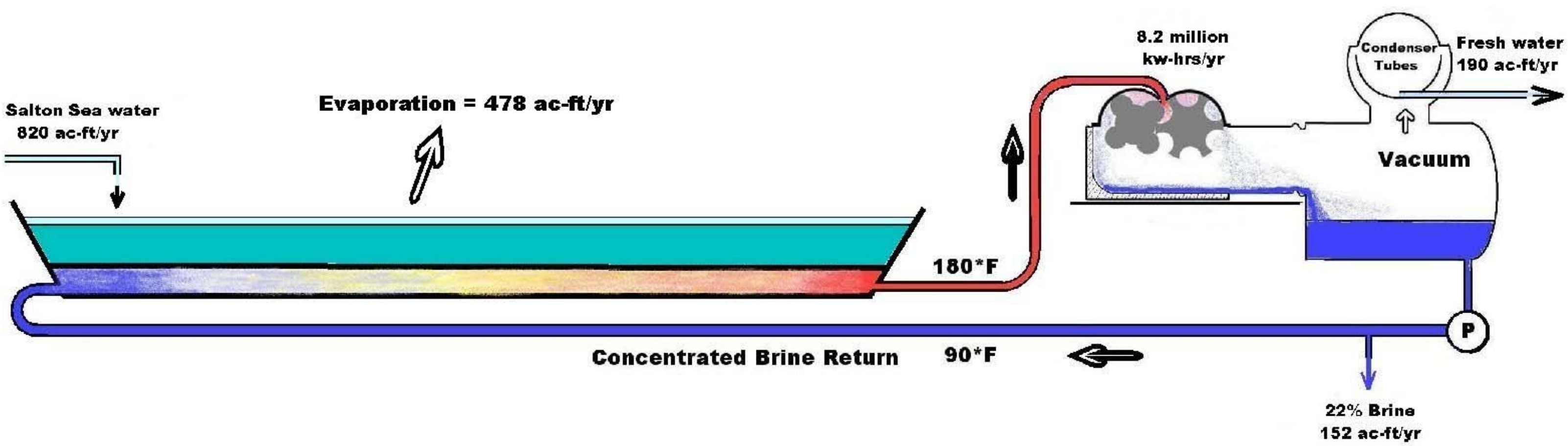
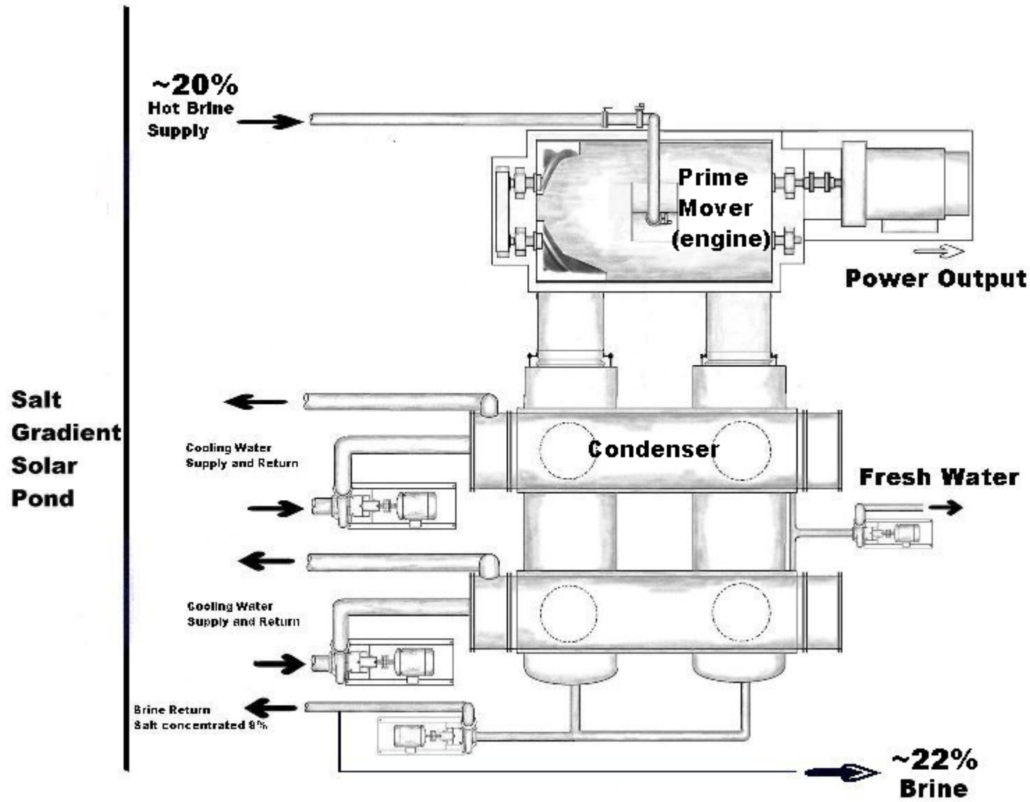


Figure 2

Plant Layout



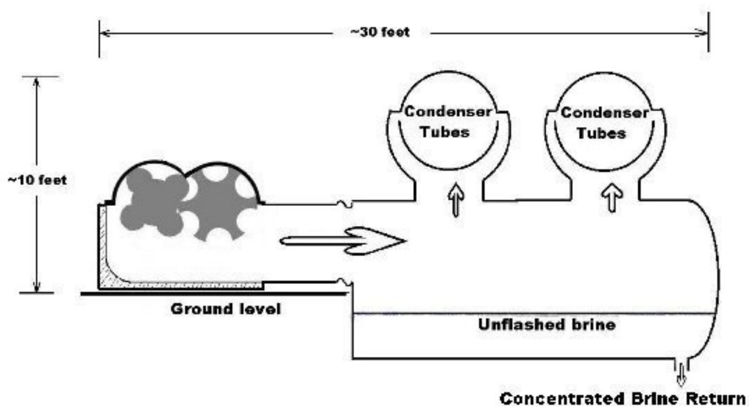


Figure 3

Water and Power

"Farm"

Cost = $2,588,000

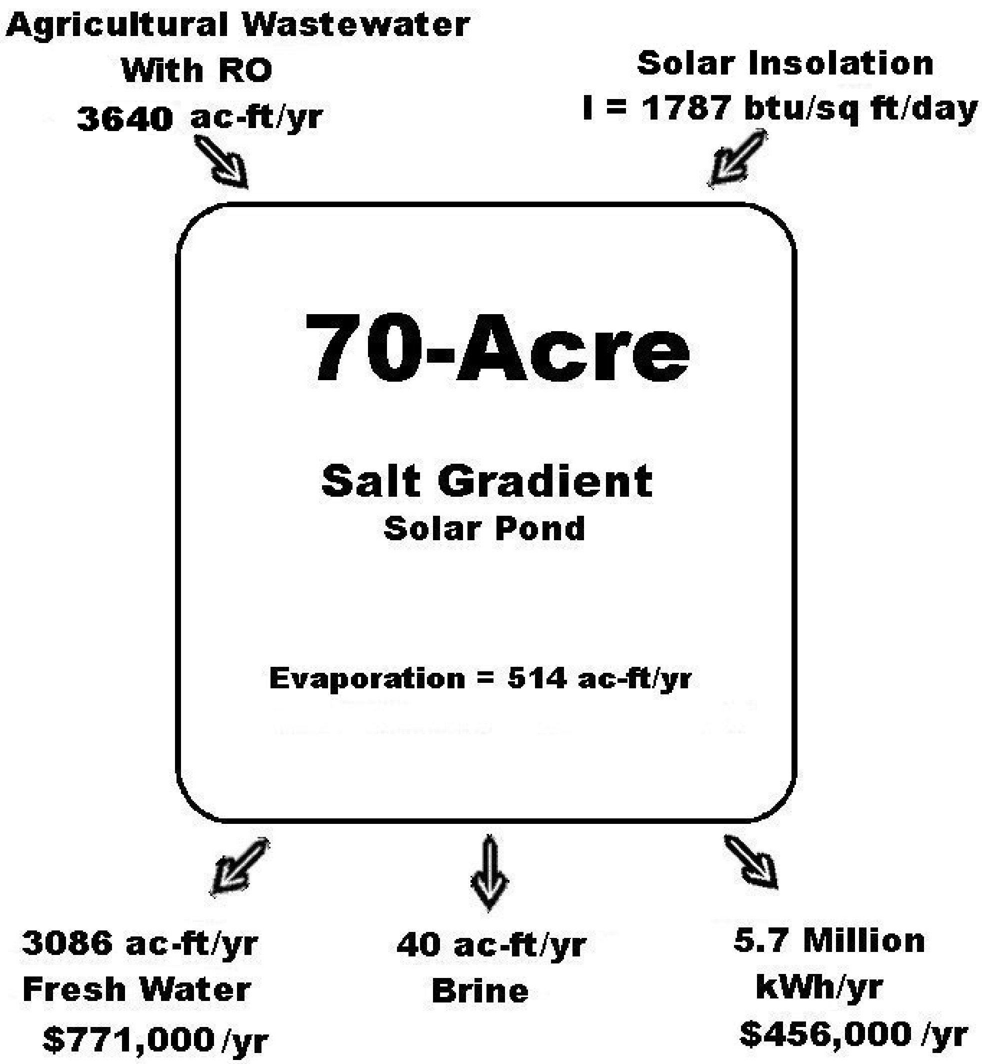


Figure 4

The Pond

The pond is a conventional nonconvecting solar pond involving three layers, the low salinity top layer, the increasing salinity inversion layer, and the high salinity bottom brine layer (see references 1 and 2). Pond depth is 5 to 7 feet.

Reference 5 discusses the heat recovery advantage of flowing the brine across the pond, counter to the cooling surface water. An additional improvement involves changing the shape of the brine flow path from wide-shallow to narrow-deep. This "shape factor" improves the pond efficiency by reducing radiation and conduction losses. The shape also reduces piping lengths. Figure 5, p. 18, shows the various elements involved.

A fiberglass slotted pipe is used to remove the hot brine from the pond bottom without disturbing the inversion layer. The flow is pulled into the prime mover by vacuum. The flow from the pond to the prime mover inlet is unrestricted, passing only through a wide-open safety stop valve.

The cooled return brine is pumped out of the vacuum exhaust and split, ½ returned to the left pond bottom, and ½ to the right. The plant operator can vary this split to help balance pond temperatures. The brine is suffused back into the pond through a plastic duct or tube with adjustable openings. An economical, cleanable, disposable method would be to use plastic coated fabric (sailcloth) sewn to form a tube with adjustable flap openings for balanced flow distribution.

The cooling water supply is skimmed from the pond surface by a (long trough-shaped) floating fiberglass frame with plastic coated cloth lashed around the outside. The frame and cloth cover form a long weir where the surface water is gathered, sent through screens, and then pulled into the cooling pumps. The returned condenser cooling water is ducted across the center of the pond through a floating lay-flat tube containing openings to spread out the flow. Again, an economical method would be to use cleanable, disposable plastic-coated fabric sewn to form a tube.

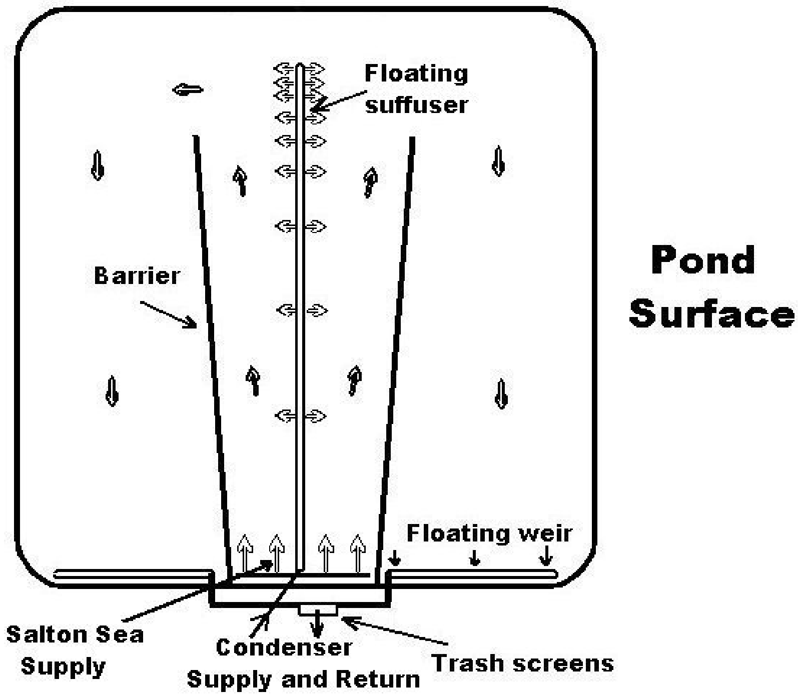
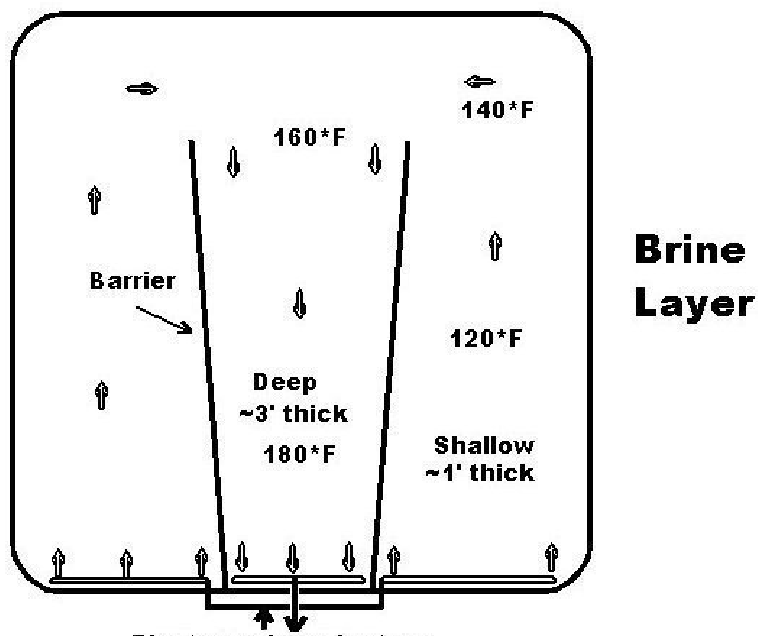

Floating
suffuser
Barrier
Pond
Surface
Floating weir
Salton Sea
Supply
Condenser
Supply and Return
Trash screens

Figure 5


140*F
160*F
Brine
Layer
Barrier
120*F
Deep
~3' thick
180*F
Shallow
~1' thick
Plant supply and return

Clarification, Mineral Deposition, and Scale Control

From solubility data, it is inferred that the Salton Sea is saturated with Gypsum ($CaSO_4$–$2H_2O$) and Calcite ($CaCO_3$). Figure 6, p. 20, shows the solubility of these minerals as a function of temperature. Chemical treatment will be needed to clarify the water to allow solar energy transmission to the bottom of the pond and to control scale buildup inside pipes and internal surfaces. Chemicals and methods used in industrial water and wastewater treatment are commonly available to control these minerals. The chemical feed amounts and exact placements are site specific to the source water. The cost involved for this proposal is unknown but should involve the following:

The intake water at the Salton Sea will need a clarifier, chlorination (or biocide), and a flocculating agent. This should be added at the fish screens, which should be designed for easy cleaning. Following the screens, the water should be mixed and held for sufficient time for coalescing. Chlorine generally needs 30 minutes to 2 hours to be effective. Chlorine also improves coagulation. Settling may or may not be needed prior to pumping to the pond.

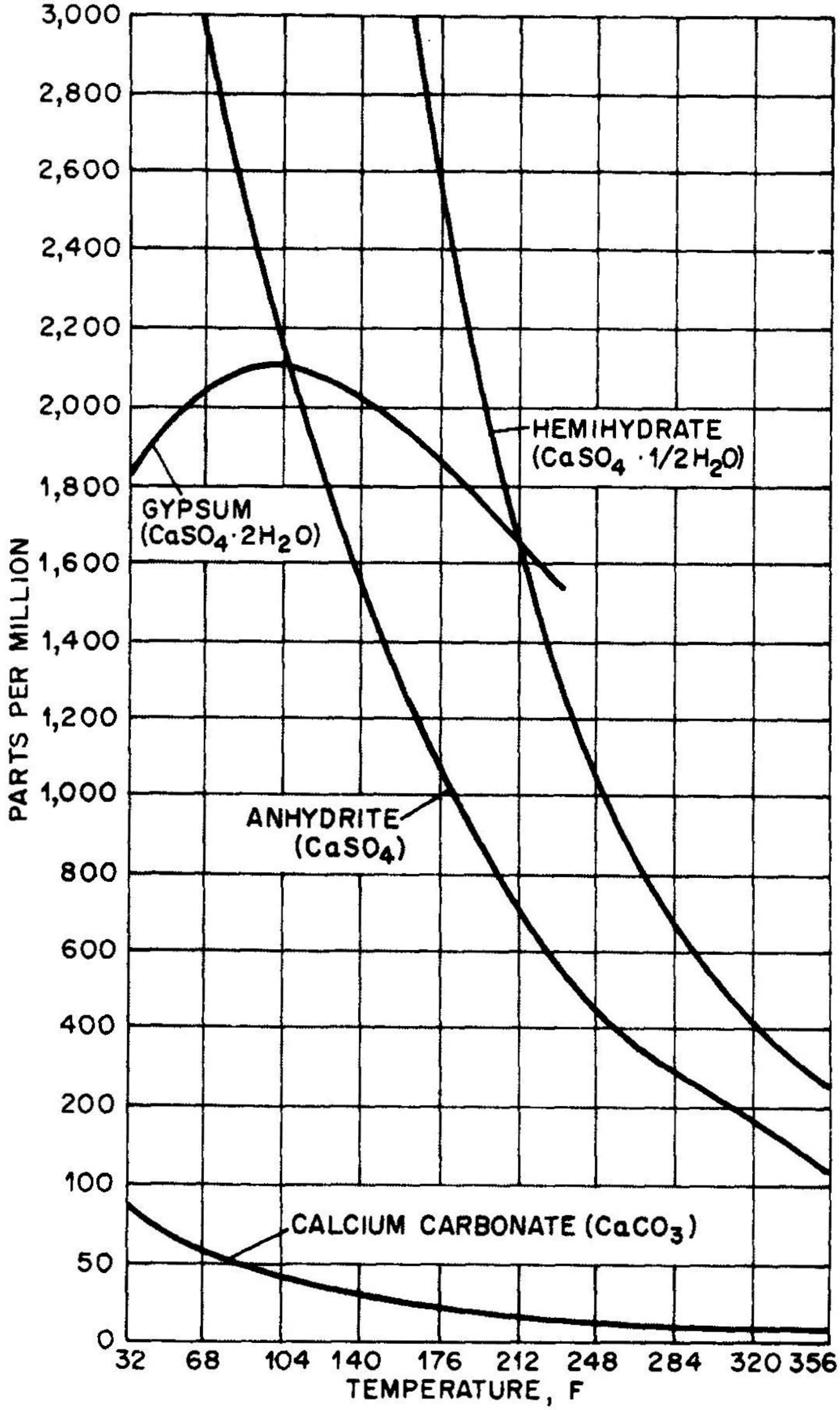
Within the pond, 61 tons/acre/year of Gypsum will come out of solution and will need to be coalesced and flocculated for precipitation and settling throughout the pond. The precipitation and settling should aid in removing wind blown suspended dust and trash.

The water entering the plant for cooling will be saturated and will have been clarified in the pond. This water will be heated in the condenser tubes. Figure 6 shows Gypsum going into solution with heating up to 104ºF; thus Gypsum scale is not expected. However, Calcite will be coming out of solution and scaling is expected. Acid, inhibitors, and periodic cleaning may be needed.

The hot brine bottom layer will also be saturated with Gypsum and Calcite. Across the plant, the brine is reduced in temperature (180ºF to 90ºF). Again looking at Figure 6, the solubility of both these minerals is increasing and no scale is expected even though the brine is being concentrated. However, the intake pipe to the prime mover will disturb the brine, which will have a scale-forming tendency. Addition of an inhibitor prior to the intake pipe may be needed.

The brine piped to the crystallizer ponds, if any, should be under-saturated. Scaling is not expected. With the brine under-saturated and deoxygenated, deep injection disposal (direct from the plant) should be facilitated.

The 61 tons/acre/year of Gypsum will precipitate and settle to the pond bottom for an annual accumulation of .7 inches/year. This is for unconsolidated material based on reference 6 without the use of a coagulant aid. If consolidated, the deposit rate is .3 inches/year. The pond design depth needs to allow for this accumulation and a plan developed for its removal (possibly every 20+ years for the production of wallboard and fertilizer?).



Solubility of calcium carbonate and calcium sulfate

Figure 6

Brine Concentration

Two methods are used to concentrate the brine. The first is by evaporation from the pond surface and the second is by spontaneous rapid boiling or flashing in the plant. An average pond surface SpGr. is estimated at 1.05. According to reference 6, the evaporation rate factor is .92 (that of fresh water), equating to a pond evaporation rate of 7.66 ft/yr. The flashing in the plant and the extraction of water is equivalent to a pond evaporation rate of 3.2 ft/yr. The energy removed from the pond in the form of electric power, bearing friction, etc, along with fresh water 15ºF above the Salton Sea supply is equivalent to ~2 inches evaporation. The heat in the brine sent to the crystallizer ponds will help in evaporation.

The total effective evaporation is 11 ft/yr. This is 60% higher than concentrating ponds and the reason for less needed acreage. If the brine is disposed of by deep injection directly from the plant, crystallizer ponds are unnecessary for even less needed acreage.

The Inversion Layer

The inversion layer is the middle layer in the pond where the salinity (density) increases with depth. This increasing density prevents the hot bottom brine layer from naturally convecting to the surface and acts as a thermal barrier or blanket, trapping in the heat. The density overcomes the buoyancy of the hot brine below. The design thickness of this layer is 3 feet.

Within the inversion layer, the salts are constantly diffusing or migrating upwards to the low salinity surface layer. However, the plant is removing fluid from the bottom layer and this produces a downward movement or flow in the pond. This downward flow is 4 to 8 times greater than the upward migration of salt. The salts are being pulled down and concentrated in the plant. In normal operation, the downward movement is approximately 4 inches per month.

With this downward movement, the inversion layer over time will have a tendency to become thinner than 3 feet. A thinner inversion layer has less of the desired insulating effect and more heat will be lost by conduction. To maintain the desired inversion layer thickness, compensation for the downward movement can be achieved by bleeding flow from just above the top of the inversion layer and mixing it with the concentrated brine that is being returned from the plant to the pond bottom. This will enable the plant operator to control the thickness and position of the inversion layer.

The relatively low salinity (density) Salton Sea supply to the pond is distributed across the surface at the plant intake where the bottom brine layer is the hottest. This provides the greatest density gradient, and thus improved inversion layer stability to this critical region of the pond.

Wind erosion and destruction of the inversion layer is of constant concern. To suppress both wind waves and standing waves, it is proposed that the pond be stabilized with a floating 40-foot square grid of PVC pipe. This would reduce the solar insolation about 1%. Wind erosion can also be suppressed with windbreaks (trees) around the pond perimeter.

Upsets/Recovery

Much as with a farmer who loses a crop and starts over, the inversion layer can be lost and provisions need to be in place to start over. One method is to reintroduce brine back into the pond bottom. 30-ac-ft may be sufficient to allow the plant to start and operate at low power and low brine temperature. The brine source could be the crystallizer ponds or an adjacent brine holding pond. Another possibility would be to flood the surface with fresh water from an adjacent fresh water holding pond. The better option appears to be the reintroduction of a thinner brine layer that would heat quickly and allow the plant to restart, possibly within a week.

Another pond upset involves an unscheduled plant outage where the pond is at risk of overheating, causing the destruction of the inversion layer. To prevent this, the hot brine can be upwelled into a floating trough where the heat is liberated to the atmosphere and the cooled brine is returned to the bottom. Approximately 3000 square feet of exposed surface should provide sufficient cooling. A fractional horsepower flow inducer should provide sufficient flow. The cooling trough may actually thermal siphon and flow naturally. With the use of removable pipe plugs and changing the floatation, the trough used to skim the surface water for plant cooling can alternately be used to reject heat from the brine, thus reducing costs.

Another option is to send hot brine to the crystallizer ponds to be cooled and then returned (concentrated) back to the pond bottom. If needed, the piping could also be used to re-establish a new brine layer.

The Plant

The two major plant components are the prime mover and the surface condensers.

The prime mover, discussed in reference 5, is constructed of titanium. The rotor size is 4 feet diameter by 12 feet long directly connected to a synchronous generator at 1200 rpm. Speed and load are governor controlled by a variable converging nozzle located in the inlet port. The bearings are antifriction, spherical roller, pillow block mounted with a full load life of 100,000 hrs. re-greased twice yearly. The timing gears are spur. The shaft seals are water-flooded and water-backed mechanical.

Abnormal operating conditions such as vibration, over speed, high load, high liquid level, and high temperatures automatically trip and close the intake safety stop valve. The plant is started manually and automatically synchronized with the grid. Approximately 25 kW for 15 minutes are needed to start the plant. The governor is speed sensing, independent of the grid. The plant and pond management can be fully automated.

Dual exhausts and dual condensers provide for a small pressure drop from the rotors to the condenser tubes and allow for uninterrupted (one condenser) operation. The vacuum exhaust from the prime mover is directed into large diameter knock-out drums where the flashed vapor and brine separate. The vapor is directed up into conventional surface condensers. The unflashed brine, stripped of non-condensable gases and now concentrated, is pumped back to the pond bottom to begin again its heating journey.

Non-condensable gases are removed with a liquid ring vacuum pump. The unflashed brine is pumped back to the pond using (titanium) centrifugal pumps designed for a low net pump suction head and with water-flooded water-backed mechanical seals. The pumps are constant speed and controlled by level switches located in the exhaust separator. The brine liquid level is allowed to rise and fall ~2 feet. Soft start relays are use to control the pump motors.

Initial startup and brine concentrating operation can begin with as little as 30ºF temperature difference between the cooling surface water and the bottom brine layer. In the winter, a brine temperature of 100ºF should be sufficient.

All piping and surfaces exposed to the brine are made from either plastic, reinforced plastic, or titanium. The condenser housing can be stainless steel. The tubes and end plates are titanium. The plant consumes internally less than 1 gpm of the fresh water produced.

Seasonal Swings

Assuming an average June insolation of 2545 btu/day/square ft, a pond surface temperature of 85ºF, and no transient thermal lags (steady state operation), the plant characteristics are as follows:

Salton Sea flow to pond	941 gpm
Plant inlet temperature	180ºF
Condenser temperature	104ºF
Plant inlet flow	2546 gpm
Net Plant power output	1274 kW
Brine flow to crystallizers	184 gpm
Fresh water output	185 gpm

Assuming an average December insolation of 982 btu/day/square ft, a pond surface temperature of 60ºF, and steady state operation, the plant characteristics are as follows:

Salton Sea flow to pond	199 gpm
Plant inlet temperature	180ºF
Condenser temperature	90ºF
Plant inlet flow	828 gpm
Net Plant power output	563 kW
Brine flow to crystallizers	39 gpm
Fresh water output	68 gpm

The plant/pond has the ability to operate efficiently over a broad range of inlet temperatures. It is interesting to note that with a lower inlet temperature (150ºF) the pond needs only to heat the returned brine 60ºF (vs. 90ºF) and will support a higher flow rate. Counter intuitive is the higher brine and fresh water production at 150ºF. The comparison in performance is as follows: (Insolation = 1850 btu/day/square ft)

Pond Brine Temperature	150ºF	180ºF	202ºF
Salton Sea flow to pond	534 gpm	516 gpm	502 gpm
Plant inlet temperature	150ºF	180ºF	202ºF
Condenser temperature	90ºF	90ºF	90ºF
Plant inlet flow	2510 gpm	1563 gpm	1195 gpm
Net power output	776 kW	1089 kW	1201 kW
Brine flow to crystallizers	104 gpm	101 gpm	98 gpm
Fresh water output	143 gpm	128 gpm	117 gpm

Reference 6 predicts a June/July concentrator pond input flow of 17,000 gpm and output flow (to the crystallizers) of 1630 gpm. Reference 6 also predicts a December input flow of 1630 gpm and output flow of 190 gpm. Up to 50% of the crystallizer ponds will be idle in the winter. Using this proposal, brine can be stored in the summer months for winter delivery, thus making full use of the crystallizer ponds. Storage would involve a +/- 2-inch swing in the pond brine layer thickness.

Cost Estimate Using Salton Sea Water

60 acre Plant/Pond costs

Using Salton Sea water

Item	Weight (lbs)	Cost($)
Prime mover-1400 kW generator on skid pad. Rotors are 4 feet in diameter, 12 feet long, directly connected to the generator at 1200 RPM. Each titanium rotor weights 3,800 lb. The titanium housing inner wall weighs 4,200 lb. The generator weights 12,000 lb. The balance of construction is reinforced concrete.	40,000	750,000
Condensers (2); 6,000 square feet each, titanium tubes, double pass, 7,500 lbs each	15,000	250,000
Exhaust separators (2), 6 feet diameter x 20 feet long reinforced titanium	11,000	70,000
Pumps: (2) Cooling water at 15 hp, 4000 gpm each; Brine return pumps, (4) at 7 ½ hp, 750 gpm, with double mechanical seals; Fresh water pumps, (2) at 2 hp, 130 gpm; Plus valves and fittings.	5,000	30,000
Fiberglass piping, pond suffusers, intakes, and off-line pond cooling	9,000	45,000
Liquid jet vacuum pumps (2), 5 hp each, with fittings	3,000	18,000
Governor control system, plant electrical, safety shutdown, sensors and pond monitoring system	5,000	75,000
60 acre pond, grading, and bank erosion protection.		400,000
Salton Sea water intake pump/piping, brine pump/piping to crystallizers, and fresh water pump/piping, 6000 ft	14,000	36,000
Chemical feed system for clarification and scale control.	1,000	10,000
Pond barrier, 6 x 2800 feet sailcloth with weights, floats, with insulation on bottom 4 feet. Wave suppression floating plastic pipe, 40 foot grid, anchors every 40 feet on perimeter	40,000	80,000
Electrical wiring for overall plant	2,000	20,000
40 x 50 foot Building for prime mover-generator, and electrical equipment.	15,000	40,000
40 yards of concrete for pads, supports, anchors, and pump pickup holding cistern. (Weight not shown in column)		20,000
Utility connection and switchgear. Rough estimate with unknown site specific factors	-	100,000
Site engineering, construction, and startup	-	50,000
Total plant weight and cost estimate	160,000 lbs	$1,994,000

Annual Plant Operating Cost Estimate

Using Salton Sea Water

Item	$/yr
$2 million loan: Amortized over 30 years @ 7% interest	160,000
Land mortgage or lease payment	12,000
Salaries: Plant operator + 2 unskilled +benefits	140,000
Plant maintenance: tools, replacement parts, repair, and pond cleaning	40,000
Chemicals for clarification and scale control	+?
Overhead: clerical, accounting, insurance, professional services and office supplies	50,000
Reserve for one major inspection and repair every 10 years	30,000
Total operating cost estimate	432,000+

Annual Income Estimate

Using Salton Sea Water

Item	$/yr
Income from sale of electricity: 8.2 million kWh @ $.08/kWh 21 days/yr offline	656,000
Income from sale of water: 190 ac-ft @ $250/ac-ft	47,000
Total Income Estimate	$ 703,000

Other Applications

The source water for this proposal is Salton Sea water, wastewater draining into the Sea, Colorado River Basin water, or Delta water. The source water just as well could be local saline or polluted groundwater. The groundwater can be extracted and replaced with the produced freshwater and stored. During drought years, this stored fresh water can be used to stabilize the Sea elevation. During wet years the stored water can be exported. Longer term, with the Sea as a fresh water lake, the lake water can be exported.

Globally, beyond the Imperial Valley, vast areas of land are available for water and power production. There are large areas of irrigated farmland that have become and continue to become salt laden, waterlogged, and water polluted. It is estimated that a world total of 50 million acres are adversely impacted and increasing at 20,000 acres per year. In the middle east, in Israel and Jordan for example, good water and power are in short supply, and this technology can be used to great benefit, including political.

Another application is along desert coastlines where seawater is pumped in, water and power produced, and the concentrated brine returned to the ocean or the salts recovered. Resorts, high quality drip irrigated crops, hothouses, and aquaculture are just a few of the endless possibilities.

Reference 5 describes other applications for the prime mover, primarily on low temperature geothermal resources.

Self-Evaluation

This proposal is unlike any found in the "Salton Sea Alternative Evaluation Final Report, 9/97".

Construction time for the first SPP is estimated at 18 months. Subsequent plants, possibly larger, can be constructed in parallel and installed as ponds are completed.

With respect to renewable energy, waterfowl may find roosting on a warm pond an attractive alternative to deadly whacks by wind machine blades. SPPs are candidates for supporting the need to meet the Renewable Portfolio Standard goals. This gives the Cognizant Agency the opportunity to solicit others to carry most of the cost of funding this plan in return for their share of the electricity.

The low elevation pond/plants with trees as windbreaks can be located with little visual or noise impact.

Power lines can be underground.

Plant maintenance crews can travel to each plant, dividing and sharing the costs. SPPs will be monitored and controlled remotely.

Glossary

SPP = Solar Salt Gradient Pond/Plant
msl = mean sea level
Ag or ag = Agricultural
RO = reverse osmosis
ac-ft = acre feet = 326,000 gallons
ac-ft/yr = acre feet per year
gpm = gallons per minute
hp = horsepower = .746 kilowatt
kW = kilowatts
kWh = Average kilowatts produced in a one hour time period. Constantly producing one kilowatt for one hour is one kWh. Constantly producing one kilowatt for one year is 8,760 kWh.
kWh/yr = kWh produced in a one year time period. As an example, a 1500 kW (1.5 MW) installed wind turbine, that runs intermittently, can be expected to produce about the same amount of power (kWh/yr) as a 500 KW power source running constantly at 500 kW. Similarly, a 1000 watt (one kilowatt) installed photovoltaic solar collector can be expected to produce about the same amount of power (kWh/yr) as a 200 watt power source running constantly day and night at 200 watts.

Technology

Salt Gadient Solar Pond (from various Web sources)

Salt gradient solar ponds were not invented, they were discovered in nature and first observed in Transylvania in the early 1900s. Solar ponds work in winter, even when covered with a sheet of ice and surrounded by drifts of snow. A salt gradient pond has three distinct layers of brine (a mixture of salt and water) of varying concentrations. The top layer is near ambient and has low salt content. The bottom layer is hot, typically 160 F to 212 F (71 C to 100 C), and is very salty. The important gradient zone separates these zones. The gradient zone acts as a transparent insulator, permitting the sunlight to be trapped in the hot bottom layer (from which useful heat is withdrawn). This is because the salt gradient, which increases the brine density with depth, counteracts the buoyancy effect of the warmer water below (which would otherwise rise to the surface and lose its heat to the air).

As sunlight enters the pond, solar radiation is absorbed. As a result, the water near the bottom of the pond becomes warm, over 200°F (93.3°C). Although all of the layers store some heat, the bottom layer stores the most. Even when it becomes warm, the bottom layer remains denser than the upper layers, thus inhibiting convection. The solar pond is thus a unique energy trap with the added advantage of built-in long-term heat storage capacity. Its cost per square meter of solar collector area is considerably lower, about one-fifth that of flat plate solar collectors where low grade heat (i.e. below 100 deg. C) is collected.

The Salt Gradient Solar Pond/Plant Engine

The SPP plant features a unique low-pressure steam engine, which relates back to a twin-screw supercharger invented in the 1930's by Mr. Alf Lysholm who was then Chief Engineer of SRM (Svenska Rotor Maskiner AB). Roger S. Sprankel extended the design to an expander with specific application objectives, resulting in two patents. Mr. Sprankle reduced his concepts to practice within his Hydrothermal Power Co., Ltd. His present design departs from helical rotors used in all prior designs. Hot brine from the bottom of the salt gradient pond will flow through this new-design steam engine, or expander, in trapped volumes within the machine. As the trapped volume increases, steam is released to fill the volume and to produce the driving fluid. From the exhaust, separated steam is condensed, dropping the pressure and producing the pressure drop across the engine, which makes it run. Sizes and rates are selected so as to drive a synchronous generator for electricity production. The steam condensate is essentially distilled water and the residual brine is more concentrated than was drawn from the pond. Thermodynamically speaking, the path through the engine causes isentropic expansion from the saturated liquid line. The hot brine travels with the steam, continually giving up its thermal energy and more steam along the path.